PROCEEDINGS
OF
THE ROYAL SOCIETY.

1840. No. 42.

February 27, 1840.

The MARQUIS of NORTHAMPTON, President, in the Chair.

William Jory Henwood, Esq., was balloted for, and duly elected into the Society.

The reading of a paper entitled, "On the Chemical Action of the Rays of the Solar Spectrum on Preparations of Silver and other Substances, both metallic and non-metallic; and on some Photographic processes;" by Sir John F. W. Herschel, Bart., V.P.R.S., &c., was resumed but not concluded.

The President stated to the Meeting, that, accompanied by the Treasurer, Secretary, and other Members of the Council, he had, on Tuesday last, presented the Address to His Royal Highness Prince Albert, to which His Royal Highness returned the following gracious answer:

"It has been the source of great pleasure to me that my arrival in this country should have been hailed with such flattering demonstrations of sincere affection. Amongst the many that have reached me, none have given me more satisfaction than that which I have just received from the Council of the Royal Society."

March 5, 1840.

The MARQUIS of NORTHAMPTON, President, in the Chair.

Captain John Theophilus Boileau was balloted for, and duly elected into the Society.

The reading of a paper entitled, "On the Chemical Action of the Rays of the Solar Spectrum on Preparations of Silver and other Substances, both metallic and non-metallic; and on some Photographic Processes;" by Sir John F. W. Herschel, Bart., V.P.R.S., &c., was resumed and concluded.

The object which the author has in view in this memoir is to place on record a number of insulated facts and observations respecting the relations both of white light, and of the differently refrangible rays, to various chemical agents which have offered themselves to his notice in the course of his photographic experiments, suggested by the announcement of M. Daguerre's discovery. After recapitulating the heads of his paper on this subject, which was read to the Society on the 14th of March, 1839, he remarks, that one of the most important branches of the inquiry, in point of practical utility, is into the best means of obtaining the exact reproduction of indefinitely multiplied facsimiles of an original photograph, by which alone the publication of originals may be accomplished; and for which purpose the use of paper, or other similar materials, appears to be essentially requisite. In order to avoid circumlocution, the author employs the terms *positive* and *negative* to express, respectively, pictures in which the lights and shades are the same as in nature, or as in the original model, and in which they are the opposite; that is, light representing shade; and shade, light. The terms *direct* and *reverse* are also used to express pictures in which objects appear, as regards right and left, the same as in the original, and the contrary. In respect to photographic publication, the employment of a camera picture avoids the difficulty of a double transfer, which has been found to be a great obstacle to success in the photographic copying of engravings or drawings.

The principal objects of inquiry to which the author has directed his attention in the present paper, are the following. First, the means of fixing photographs; the comparative merits of different chemical agents for effecting which, such as hyposulphite of soda, hydriodite of potash, ferrocyanate of potash, &c., he discusses at some length; and he notices some remarkable properties, in this respect, of a peculiar agent which he has discovered.

2. The means of taking photographic copies and transfers. The author lays great stress on the necessity, for this purpose, of preserving, during the operation, the closest contact of the photographic paper used with the original to be copied.

3. The preparation of photographic paper. Various experiments are detailed, made with the view of discovering modes of increasing the sensitiveness of the paper to the action of light; and particularly of those combinations of chemical substances which, applied either in succession or in combination, prepare it for that action. The operation of the oxide of lead in its saline combinations as a mordent is studied; and the influence which the particular kind of paper used has on the result, is also examined, and various practical rules are deduced from these experiments. The author describes a method of precipitating on glass a coating possessing photographic properties, and thereby of accomplishing a new and curious extension of the art of photography. He observes, that this method of coating glass with films of precipitated argentine, or other compounds, affords the only effectual means of studying their habitudes on exposure to light, and of estimating their degree of sensibility, and other particulars of their deportment under the influence of reagents. After

stating the result of his trials with the iodide, chloride, and bromide of silver, he suggests that trials should be made with the fluoride, from which, if it be found to be decomposed by light, the corrosion of the glass, and consequently an etching, might possibly be obtained, by the liberation of fluorine.

As it is known that light reduces the salts of gold and of platinum, as well as those of silver, the author was induced to make many experiments on the chlorides of these metals, in reference to the objects of photography; the details of which experiments are given. A remarkable property of hydriodic salts, applied, under certain circumstances, to exalt the deoxidating action of light, and even to call into evidence that action, when it did not before exist, or else was masked, is then described.

4. The chemical analysis of the solar spectrum forms the subject of the next section of his paper. It has long been known that rays of different colours and refrangibilities exert very different degrees of energy in effecting chemical changes; and that those occupying the violet end of the spectrum possess the greatest deoxidating powers. But the author finds that these chemical energies are distributed throughout the whole of the spectrum; that they are not a mere function of the refrangibility, but stand in relation to physical qualities of another kind, both of the ray and of the analysing medium; and that this relation is by no means the same as the one which determines the absorptive action of the medium on the colorific rays. His experiments also show that there is a third set of relations concerned in this action, and most materially influencing both the amount and the character of the chemical action on each point of the spectrum; namely, those depending on the physical qualities of the substance on which the rays are received, and whose changes indicate and measure their action.

The author endeavoured to detect the existence of inactive spaces in the chemical spectrum, analogous to the dark lines in the luminous one; but without any marked success. The attempt, however, revealed several curious facts. The maximum of action on the most ordinary description of photographic paper, namely, that prepared with common salt, was found to be, not beyond the violet, but about the confines of the blue and green, near the situation of the ray F in Fraunhofer's scale: and the visible termination of the violet rays nearly bisected the photographic image impressed on the paper: in the visible violet rays there occurred a sort of minimum of action, about one-third of the distance from Fraunhofer's ray H, towards G: the whole of the red, up to about Fraunhofer's line C appears to be inactive; and lastly, the orange-red rays communicate to the paper a brick-red tint passing into green and dark blue. Hence are deduced, first, the absolute necessity of perfect achromaticity in the object-glass of a photographic camera; and secondly, the possibility of the future production of naturally coloured photographs.

5. The extension of the *visible* prismatic spectrum beyond the space ordinarily assigned to it, is stated as one of the results of these researches; the author having discovered that beyond the extreme

violet rays there exist luminous rays affecting the eyes with a sensation, not of violet, or of any other of the recognised prismatic hues, but of a colour which may be called *lavender-grey*, and exerting a powerful deoxidating action.

6. Chemical properties of the red end of the spectrum. The rays occupying this part of the spectrum were found to exert an action of an opposite nature to that of the blue, violet, and lavender rays. When the red rays act on prepared paper in conjunction with the diffused light of the sky, the discolorating influence of the latter is suspended, and the paper remains white; but if the paper has been already discoloured by ordinary light, the red rays change its actual colour to a bright red.

7. The combined action of rays of different degrees of refrangibility is next investigated; and the author inquires more particularly into the effects of the combined action of a red ray with any other single ray in the spectrum; whether any, and what differences exist between the joint, and the successive action of rays of any two different and definite refrangibilities; and whether this action be capable, or not, of producing effects, which neither of them, acting alone, would be competent to produce. The result was that, although the previous action of the less refrangible rays does not appear to modify the subsequent effects produced by the more refrangible; yet the converse of this proposition does not obtain, and the simultaneous action of both produces photographic effects very different from those which either of them, acting separately, are capable of producing.

8. In the next section, the chemical action of the solar spectrum is traced much beyond the extreme red rays, and the red rays themselves are shown to exercise, under certain circumstances, a blackening or deoxidating power.

9. The author then enters into a speculation suggested by some indications which seem to have been afforded of an absorptive action in the sun's atmosphere; of a difference in the chemical agencies of those rays which issue from the central parts of his disc, and those which, emanating from its borders, have undergone the absorptive action of a much greater depth of his atmosphere; and consequently of the existence of an absorptive solar atmosphere extending beyond the luminous one.

10. An account is next given of the effect of the spectrum on certain vegetable colours, as determined by a series of experiments, which the author has commenced, but in which the unfavourable state of the weather has, as yet, prevented him from making much progress.

11. The whitening power of the several rays of the spectrum under the influence of hydriodic salts, on paper variously prepared and previously darkened by the action of solar light. The singular property belonging to the hydriodate of potash of rendering darkened photographic paper susceptible of being whitened by further exposure to light is here analysed, and shown to afford a series of new relations among the different parts of the spectrum, with respect to their chemical actions.

12. The Analysis of the Chemical Rays of the Spectrum by absorbent media, which forms the subject of the next section, opens a singularly wide field of inquiry; and the author describes a variety of remarkable phenomena which have presented themselves in the course of his experiments on this subject. They prove that the photographic properties of coloured media do not conform to their colorific character; the laws of their absorptive action as exerted on the chemical, being different and independent of those on the luminous rays: instances are given of the absence of any darkening effect in green and other rays of the more refrangible kind, which yet produce considerable illumination on the paper that receives them.

13. The exalting and depressing power exercised by certain media, under peculiar circumstances of solar light, on the intensity of its chemical action. This branch of the inquiry was suggested by the fact, noticed by the author in his former communication, that the darkening power of the solar rays was considerably increased by the interposition of a plate of glass in close contact with the photographic paper. The influence of various other media, superposed on prepared paper, was ascertained by experiment, and the results are recorded in a tabular form.

14. The paper concludes with the description of an *Actinograph*, or self-registering Photometer for meteorological purposes: its objects being to obtain a permanent and self-comparable register and measure, first, of the momentary amount of general illumination in the visible hemisphere, which constitutes day-light; and secondly, of the intensity, duration, and interruption of actual sunshine, or, when the sun is not visible, of that point in the clouded sky behind which the sun is situated.

In a postscript, dated March 3rd, 1840, the author states that he has discovered a process by which the calorific rays in the solar spectrum are made to affect a surface properly prepared for that purpose, so as to form what may be called a *thermograph* of the spectrum; in which the intensity of the thermic ray of any given refrangibility is indicated by the degree of whiteness produced on a black ground, by the action of the ray at the points where it is received at that surface, the most remarkable result of which is the insulation of *heat-spots* or thermic images of the sun quite apart from the great body of the thermic spectrum. Thus the whole extent over which prismatic dispersion scatters the sun's rays, including the calorific effect of the least, and the chemical agency of the most refrangible, is considerably more than twice as great as the Newtonian coloured spectrum.

In a second note, communicated March 12, 1840, the author describes his process for rendering visible the thermic spectrum, which consists in smoking one side of very thin white paper till it is completely blackened, exposing the white surface to the spectrum and washing it over with alcohol. The thermic rays, by drying the points on which they impinge more rapidly than the rest of the surface, trace out their extent and the law of their distribution by a whiteness so induced on the general blackness which the whole surface acquires by the absorption of the liquid into the pores of the paper. He also explains a method by which the impression thus made, and which is only transient, can be rendered permanent.

This method of observation is then applied to the further examination of various points connected with the distribution of the thermic rays, the transcalescence of particular media, the polarization of radiant heat (which is easily rendered sensible by this method), &c. The reality of more or less insulated spots of heat distributed at very nearly equal intervals along the axis of the spectrum (and of which the origin is *probably* to be sought in the flint glass prism used—but *possibly* in atmospheric absorption) is established. Of these spots, two of an oval form, are situated, the one nearly at, and the other some distance beyond the extreme red end of the spectrum, and are less distinctly insulated; two, perfectly round and well-insulated, at greater distances in the same direction; and one, very feeble and less satisfactorily made out, at no less a distance beyond the extreme red than 422 parts of a scale in which the whole extent of the Newtonian coloured spectrum occupies 539.

A paper was also read entitled, " Remarks on the Theory of the Dispersion of Light, as connected with Polarization ; " by the Rev. Baden Powell, M.A., F.R.S., and Savilian Professor of Geometry, Oxford.

Since the publication of a former paper on the subject referred to, the author has been led to review the subject in connexion with the valuable illustrations given by Mr. Lubbock of the views of Fresnel; and points out, in the present supplement, in what manner the conclusions in that paper will be affected by these considerations.

A paper was also read, entitled, " Further Particulars of the Fall of the Cold Bokkeveld Meteorite ;" by Thomas Maclear, Esq., F.R.S., in a letter to Sir John F. W. Herschel, Bart., K.H., V.P.R.S., &c. communicated by Sir John Herschel.

This communication, which is supplementary to the one already made to the Society by Mr. Maclear, contains reports, supported by affidavits, of the circumstances attending the fall of a meteoric mass in a valley near the Cape of Good Hope. The attention of the witnesses had been excited by a loud explosion which took place in the air, previous to the descent of the aerolite, and which was attended by a blue stream of smoke, extending from north to west. Some of the fragments which had been seen to fall, and which had penetrated into the earth, were picked up by the witnesses. One of them falling on grass caused it to smoke ; and was too hot to admit of being touched. The mass which was sent to England by H.M.S. Scout, weighed, when first picked up, four pounds. The paper is accompanied by a map of the district, showing the course of the aerolite.

A paper was also read, entitled, " An account of the Shooting Stars of 1095 and 1243 ;" by Sir Francis Palgrave, K.H., F.R.S., &c.

The author gives citations from several chronicles of the middle ages, descriptive of the remarkable appearance of shooting stars which occurred on the 4th of April, 1095, on the testimony of independent witnesses both in France and England. One of them describes them as " falling like a shower of rain from heaven upon the earth :" and in another case, a bystander, having noted the spot where the aerolite fell, " cast water upon it, which was raised in steam, with a great noise of boiling." The Chronicle of Rheims describes the appearance as if all the stars in heaven were driven, like dust, before the wind. A distinct account of the shooting stars of July 26th, 1293, is given by Matthew Paris.

March 12, 1840.

The MARQUIS of NORTHAMPTON, President, in the Chair.

A paper was read, entitled " On certain variations of the mean height of the Barometer, mean temperature and depth of Rain, connected with the Lunar Phases, in the cycle of years from 1815 to 1823." By Luke Howard, Esq., F.R.S.

The table given in this paper contains the results of calculations relating to the objects specified in the title ; cast into periods of six, seven, or eight days, so as to bring the day of the lunar phase belonging to it in the middle of the time. The observations were all made in the neighbourhood of London. It appears from them that in the period of the last quarter of the moon the barometer is highest, the temperature a little above the mean, and the depth of rain the smallest. In the period of the new moon, both the barometer and temperature are considerably depressed, and the rain increased in quantity. The influence of the first quarter shows itself by the further depression of the barometer ; but the temperature rises almost to the point from which it had fallen, and the rain still increases, but not in an equal ratio. Lastly, the full moon again reduces the temperature ; while the barometer attains its maximum mean height, and the quantity of rain is the greatest. Thus it appears, that during this lunar cycle, the approach of the last quarter is the signal for the clearing up of the air, and the return of sunshine.

A paper was also read, entitled " On the theory of the dark bands formed in the solar spectrum from partial interception by transparent plates." By the Rev. Baden Powell, M.A., F.R.S., Savilian Professor of Geometry in the University of Oxford.

This paper contains the mathematical investigation of the phenomena of peculiar dark bands crossing the prismatic spectrum, when half the pupil of the eye, looking through the prism, is covered by a thin plate of any transparent substance, the edge being turned from the violet towards the red end of the spectrum ; and which were first noticed by Mr. Fox Talbot, and were ascribed by Sir David Brewster to a new property of light, consisting of a peculiar kind of polarity.

The author shows, that on the undulatory theory, in all cases, a difference of retardation between the two halves of each primary pencil throughout the spectrum may give bands within certain limits; and that it affords a complete explanation of the phenomena in question.

March 19, 1840.

The MARQUIS of NORTHAMPTON, President, in the Chair.

A paper was read, entitled "Contributions to Terrestrial Magnetism." By Major Edward Sabine, R.A., V.P.R.S.

An increased activity has recently been given to researches in terrestrial magnetism, with the definite object of obtaining correct maps of the magnetic phenomena, corresponding to the present epoch, over the whole surface of the globe. To aid these researches, and to facilitate the comparison of the general theory of M. Gauss with the facts of observation, maps have been constructed of the magnetical lines, both as computed by the theory, and as derived from observations already obtained. The theoretical and actual lines of the declination and intensity have thus been represented in maps recently published in Germany and England, as have also the lines of the inclination computed by theory; but the corresponding map or the latter element derived from observations is yet wanting. The object of the present communication is to supply this desideratum, as far as regards the portion of the globe contained between the parallels of 55° N. and 55° S., and the meridians of 20° E. and 80° W.; comprising the Atlantic ocean, and the adjacent coasts of the continents on either side.

The observations chiefly employed for this purpose are two series *made at sea*; one by Mr. Dunlop of the Paramatta observatory, in a voyage from England to New South Wales, in 1831; the other by Lieut. Sulivan of the Royal Navy, in a voyage from England to the Falkland Islands, and back, in 1838 and 1839. The observation of the magnetic dip at sea, which was commonly practised by the distinguished navigators of the last century, was unfortunately not resumed when the interest in such researches was revived on the restoration of peace: but it is by such observations only that the lines of inclination can be independently traced over those large portions of the globe which are covered by the ocean. The difficulties which attend the observation, occasioned by the motion and the iron of a ship, require the adoption of several precautions, which it is particularly desirable at this time to make generally known. The series of Messrs. Dunlop and Sulivan are discussed in this view; and the value of results obtained under circumstances of due precaution is pointed out by their success.

The position of the lines on the land portion of the map is derived from 120 determinations in various parts of Europe, Africa, and America, between the years 1834 and 1839, of which about the half are now first communicated.

The series of Messrs. Dunlop and Sulivan contain also observations of the magnetic intensity made at sea; Mr. Dunlop's by the method of horizontal vibrations, and Lieut. Sulivan's by the instrument and method devised by Mr. Fox. The degree of precision which may be obtained by experiments thus conducted, is shown by the comparison of these observations with each other, and with the isodynamic lines previously derived from observations made on land.

The first section of this paper concludes with discussions on the relative positions of the lines of least intensity and of no dip, and of the secular change which the latter line has undergone in the ten years preceding 1837.

In the second section, the observations of Mr. Dunlop are combined with recent observations on the coasts of Australia, by Captains Fitz Roy, Bethune, and Wickham, of the Royal Navy, to furnish a first approximation to the position and direction of the isodynamic lines over that portion of the Indian ocean which is comprised between the meridian of the Cape of Good Hope and New South Wales.

A paper was also in part read, entitled "Experimental Researches in Electricity, seventeenth series." By Michael Faraday, Esq. D.C.L., F.R.S., &c., On the source of power in the Voltaic Pile.

March 26, 1840.

The MARQUIS of NORTHAMPTON, President, in the Chair.

The reading of a paper, entitled "Researches in Electricity, Seventeenth Series: on the source of power in the Voltaic Pile." By Michael Faraday, Esq., D.C.L., F.R.S., &c., was resumed and concluded.

In this series, the author continues his experimental investigation of the origin of electric force in the voltaic pile. Having found abundant reason, in the experiments already described, to believe that the electricity of the pile has its origin in the chemical force of the acting bodies, he proceeds to examine how the circumstances which can affect the affinity of substances for each other, influence their power of roducing electric currents. First, with relation to *heat*:—circuits were made of a single metal and a single fluid, and these were examined with a view to ascertain whether, by applying heat at one of the junctions, only thermo-currents can be produced. Some peculiar effects of heat are noticed and explained; and several very necessary precautions in conducting these experiments are pointed out; and it is found, when these are taken, that heat has a decided and distinct effect over the chemical affinities of the parts of a circuit subjected to its power, and a corresponding influence on the electric current produced. This proceeds to such an extent, that, in some cases, either of two metals can be made positive or negative with respect to the other in the same fluid, solely by virtue of this power of heat.

The effect of *dilution* is then examined. For this purpose, only one metal and one fluid are used in a circuit; but the fluid is rendered more dilute at one point of contact than at the other. It was ascertained that such dilution produces little or no effect with metals which are not acted on by the electrolyte employed; and the precautions requisite as to other points are then stated. But when these are observed, still dilution is found to have a most powerful influence on the results; and, as the author believes, solely on account of its influence on the active chemical affinity. Thus copper in dilute nitric acid is positive with respect to copper in strong nitric acid; and the same is the case with lead, silver, and other metals. It is not that the piece in the weakest acid is always positive with respect to that in the stronger acid; for, in the first place, some very curious cases are given, in which a piece of metal in acid of a certain strength is *positive* with respect to a piece of the same metal in acid, either stronger or weaker; and, in the next place, other cases are stated in which the piece in the medium acid is *negative* with respect to the other piece in either stronger or weaker acid. The effect of dilution in nitric acid is such, that when certain different metals are compared together, either can, at pleasure, be made positive or negative with respect to the other; thus, of the five metals, silver, copper, iron, lead, and tin, any one of them can be made either positive or negative with respect to any other; with the sole exception of silver, which is always positive with respect to copper. The inconsistency of these results with any theory of contact electromotive force is then strongly insisted on by the author.

The next division of the paper treats of the order of the metallic elements of voltaic circuits when different electrolytes are used. It is usual to say, that metals are positive or negative with respect to each other in a certain order; but Davy, and afterwards De la Rive, showed that, in certain cases, this order is inverted. The author, by using ten metals, and seven different exciting electrolytic solutions, shows that in no two solutions is the order the same; but that changes of the most extreme kind occur in exact conformity with the changes in chemical action, which the use of the different solutions occasions.

The next division of the paper considers the very numerous cases in which voltaic circuits, often such as are able to effect decomposition, are produced without any metallic contact, and by virtue of chemical action alone; contrasting them with the numerous cases given in the previous series, where contact *without* chemical action, whether it be the contact of metal with metal, or with chemically inactive electrolytes, can produce no voltaic current.

The author then considers the sufficiency of chemical action to account for all the phenomena of the pile. He shows that chemical action does actually evolve electricity; that according as chemical action diminishes or ceases, so the electrical current diminishes or ceases also; that where the chemical action changes from side to side, the direction of the current likewise changes with it; that where no chemical action occurs, no current is produced, but that a current occurs the moment chemical action commences; and that when the chemical action which has, or could have produced a current, is, as it were, reversed or undone, the current is reversed or undone likewise; that is, it occurs in the opposite direction, in exact correspondence with the direction taken by the transferred anions and cathions. The accordance of the chemical theory of excitation with these phenomena is considered by the author as of the strictest kind.

The phenomena of thermo-electricity are considered by some philosophers as affording proofs of the efficacy of mere metallic contact in exciting an electric current. The author proceeds, therefore, to examine these phenomena in relation to such an action, and arrives at the conclusion, that they, in fact, disprove the existence of such a power. In thermo-electricity, the metals have an order which is so different from that belonging to them in any electrolyte, that it appears impossible to consider their succession, in any case, as due to any mutual effect of the metals on each other, common to both modes of excitation. Thus, in the thermo-circuit, the electric current is, at the hot place, from silver to antimony, and from bismuth to silver; but in a voltaic series, including dilute sulphuric or nitric acids, or strong nitric acid, or solution of potash, the electric current is from silver to both antimony and bismuth; whilst if the yellow sulphuret of potash be used, it is from both antimony and bismuth to silver; or if the hydro-sulphuret of potash be used, it is from bismuth to silver, and from silver to antimony; and, finally, if strong muriatic acid be used, it is precisely the reverse, that is, from antimony to silver, and from silver to bismuth. The inconsistency of these results with the contact theory is then insisted on and farther developed.

The last section of this series is on the improbability of there existing any such force as the assumed contact force. The author contends that it is against all natural analogy and probability that two particles which, being placed in contact, have by their mutual action acquired opposite electrical states, should be able to discharge these states one to the other, and yet remain in the same state they were in at the first, that is, entirely unchanged in every point by what has previously taken place; or, that the force which has enabled two particles by their mutual action to attain a certain state, should not be sufficient to make them keep that state. To admit such effects would be, he thinks, to deny that action and reaction are equal. The contact theory, according to him, assumes that a force which is able to overcome powerful resistance, both chemical and mechanical, can arise out of nothing: that, without any change in the acting matter, or the consumption of any other force, an electric current can be produced, which shall go on for ever against a constant resistance, or only be stopped, as in the voltaic trough, by the ruins which its exertion has heaped in its own course;—this, the author thinks, would be a creation of power, such as there is no example of in nature; and, as there is no difficulty in converting electrical into mechanical force through the agency of magnetism, it would, *if true*, supply us at once with a perpetual motion. Such a conclusion he considers as a strong and sufficient proof that the theory of contact is founded in error.

In a postscript, the author states that he has since found a passage in Dr. Roget's treatise on Galvanism, in the Library of Useful Knowledge, published in January 1829, in which the same argument respecting the unphilosophical nature of the contact-theory is strongly urged*.

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* "Were any further reasoning necessary to overthrow it, (namely, the voltaic theory of contact) a forcible argument might be drawn from the following consideration. If there could exist a power, having the property ascribed to it by the hypothesis, namely, that of giving continual impulse to a fluid in one constant direction, without being exhausted by its own action, it would differ essentially from all the other known powers in nature. All the powers and sources of motion with the operation of which we are acquainted, when producing their peculiar effects, are expended in the same proportion as those effects are produced; and hence arises the impossibility of obtaining by their agency a perpetual effect, or, in other words, a perpetual motion. But the electro-motive force ascribed by Volta to the metals when in contact, is a force which, as long as a free course is allowed to the electricity it sets in motion, is never expended, and continues to be exerted with undiminished power, in the production of a never-ceasing effect. Against the truth of such a supposition the probabilities are all but infinite." § 113, p. 32.